Experimental report

12/09/2016

Proposal: **5-42-407** **Council:** 4/2015

Title: SANS to measure superfluid density in chalcogenure and selenure: a comparative study to clarify peculiarities of iron based superconductor

Research area: Physics

This proposal is a new proposal

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Samples: NbSe2
FeSe

Instrument	Requested days	Allocated days	From	To
D33	5	4	11/09/2015	15/09/2015

Abstract:

The binary superconductor FeSe has a relatively structural simplicity among other Fe-based superconductors and is though to be a model system to study the mechanism of superconductivity in iron based pnictides and chalcogenides. The study of its flux lines lattice, and of the fundamental parameter of superconductivity, using a bulk probe as small angle neutron scattering is mandatory. Unfortunatly, it is very difficult to growth large enough and pure FeSe single crystals. Recently, crystals with reasonable mass have been available within our collaboration, and , using a high flux spectrometer, the experiment appears faisable. We plan to measure scattered intensity from the flux lines in the low field limit to reveal multiband and/or nodes effects in this important member of the superconducting family. In this experiment, we will also use a large NbSe2 crystal as a reference for a multiband, anisotropic SC but with a conventional pairing mechanism. Study of flux lines lattice at higher field (i.e. some Teslas) will be also conducted to reveal transition or disordering in the flux lines lattice, that may have important consequences on the transport and magnetic properties.

EXPERIMENTAL REPORT FOR 5-42-407

SANS to measure superfluid density in chalcogenure and selenure: a comparative study to clarify peculiarities of iron based superconductor

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FeSe attracts a considerable interest because it is the simplest member of the iron based new superconductors, but also due to its atypical magnetism and quite fascinating superconducting properties. Although the superconducting transition temperature of bulk FeSe is rather low $T_c \approx 8K$, it increases spectacularly under pressure (up to 37K), by carrier doping (up to 40K) and even more impressively in the single-layer limit (65K with signs of SC precursor up to 100K)). At 90K, a tetragonal to orthorhombic transition occurs. Due to the lack of large/high quality single crystals, most of the investigation of (low energy) magnetic fluctuations has been made by NMR measurements. FeSe displays no magnetic order down to the lowest temperature, but some indications of magnetic fluctuations developing under 100K have been reported. Recently, possibility of nematic order has been reported using inelastic neutron scattering.

This experiment was performed at the ILL (spectrometer D33) on a mosaic of single crystals of FeSe. The purpose was to perform neutron scattering on the flux lines lattice in this new intriguing superconductor (SC) and to measure the associated superfluid density. Due to the small magnetic contrast of flux lines in this SC and of the small crystals size, we know from the beginning that the experiment would be difficult in term of signal/background ratio. However, even with very long counting times, and after testing different values of the magnetic field, no Bragg peaks or even diffuse scattering due to the FLL could be seen. Note that all the crystals were tested before in terms of superconducting transition and crystalline quality. This lack of observable neutron scattering from the vortex lines was not expected with respect to our estimations of scattered intensity. This indicates that an unusual “disorder” destroys or at least affects the long range ordering of the FLL. This disorder potential is possibly of magnetic origin. At the end of the experiment, we see a sudden change of the central diffusion when going into the superconducting phase under a large magnetic field (B=3T), with a change of symmetry from square-like to an isotropic signal (fig.1). Importantly, this isotropic diffusion does not change when re-heating above the critical temperature, but returns to square for T>90K, i.e. above the structural transition. Unfortunately, this was the end of the beam time and no further measurement has been made.

Of course, it would be necessary to confirm these results in terms of reproducibility, and then to analyze the SANS signal to prove its magnetic nature by: by 1/ anisotropic radial regrouping and 2/ polarisation analysis. This could be the subject of a future proposal.

If the result is confirmed, it would bring strong insight into the link between the proximity of the magnetic instability, the SC state and the structural transition in this fascinating, yet puzzling, superconductor.

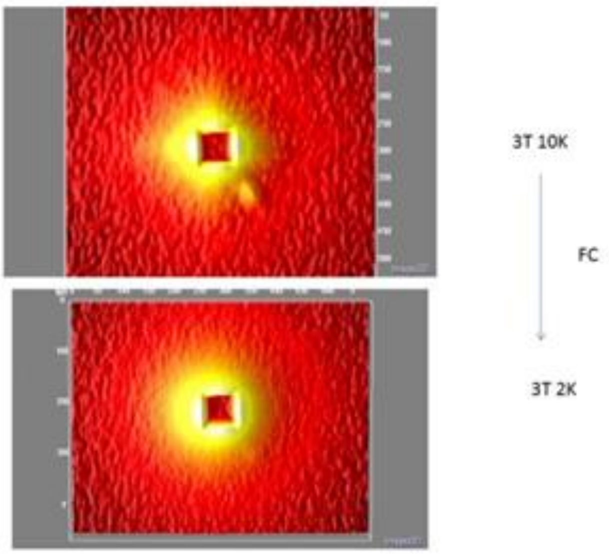

Fig1: Change of SANS signal of the FeSe sample under a large magnetic field when going into the superconducting state